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# Effect of Surface Omniphobicity on Drying by Forced Convection

**Madani Khan**
**The City College of New York**
**STAR Program**
**August, 2015**

*Integrity ★ Service ★ Excellence*

# Background

- **I am from Bangladesh.**
- **Education: The City College of New York**
- **Major: Chemistry; Minor: Education.**

# Abstract

- Low energy surfaces can strongly repel both oil and water. Recently these surfaces have been fabricated on various substrates including fabric, aluminum, stainless steel and many other materials. In this experiment we explore the use of low energy surface deposition on aluminum alloy, stainless steel and silicon substrates, to enhance the drying rate of liquids removed from the surface by forced convection. We control surface roughness by substrate abrasion and by the growth of $Al_2O_3$ nanograss to enhance liquid repellence by use of a hierarchical texture. Liquid repellence of the substrates is measured by contact angles of the probe liquids, water and hexadecane. Samples are mounted on a rigid stage constructed with a flat surface and a regulated air nozzle fixed to provide flow parallel to the substrate surface. The velocities of probe liquid droplets placed on the substrates are recorded via high-speed camera as they are moved by a constant air flow. It is shown that drops on omniphobic and superomniphobic surfaces move at increased velocity compared to untreated surfaces, and leave behind less residual liquid, resulting in a faster drying rate. 2-factor design of experiments (DOE) was implemented to explore the optimum conditions for a fast drying low energy surface. The use of DOE and the results of this experiment are merged into a lesson plan developed for $9^{th}$-$12^{th}$ grade students. These results will serve as examples low energy surfaces and their potential applications.

# Introduction

- **Explore the use of low energy surface deposition on aluminum alloy, stainless steel and silicon substrates, to enhance the drying rate of liquids removed from the surface by forced convection**
- **The velocities of probe liquid droplets placed on the substrates are recorded via high-speed camera as they are moved by a constant air flow**
- **2-factor design of experiments (DOE) is implemented to explore the optimum conditions for a fast drying low energy surface**

# Application

- **The application of this work can be used in rocket engines, rooftops, cars, umbrellas, tiles, oven, paint, or any kind of fabrics.**

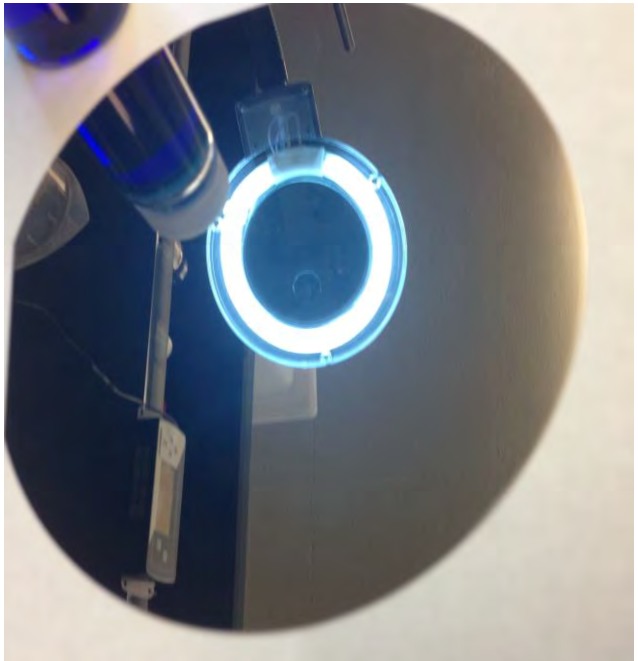

# Design of Experiment (DOE)

- **Systematic method to determine the relationship between factors affecting a process and the output of that process.**
- **Why?**
  - **Saves time**
  - **Lower cost**
  - **Reduce product material and labor complexity**
  - **Better design engineering**
- **Accessibility**
  - **Microsoft Excel or online software**

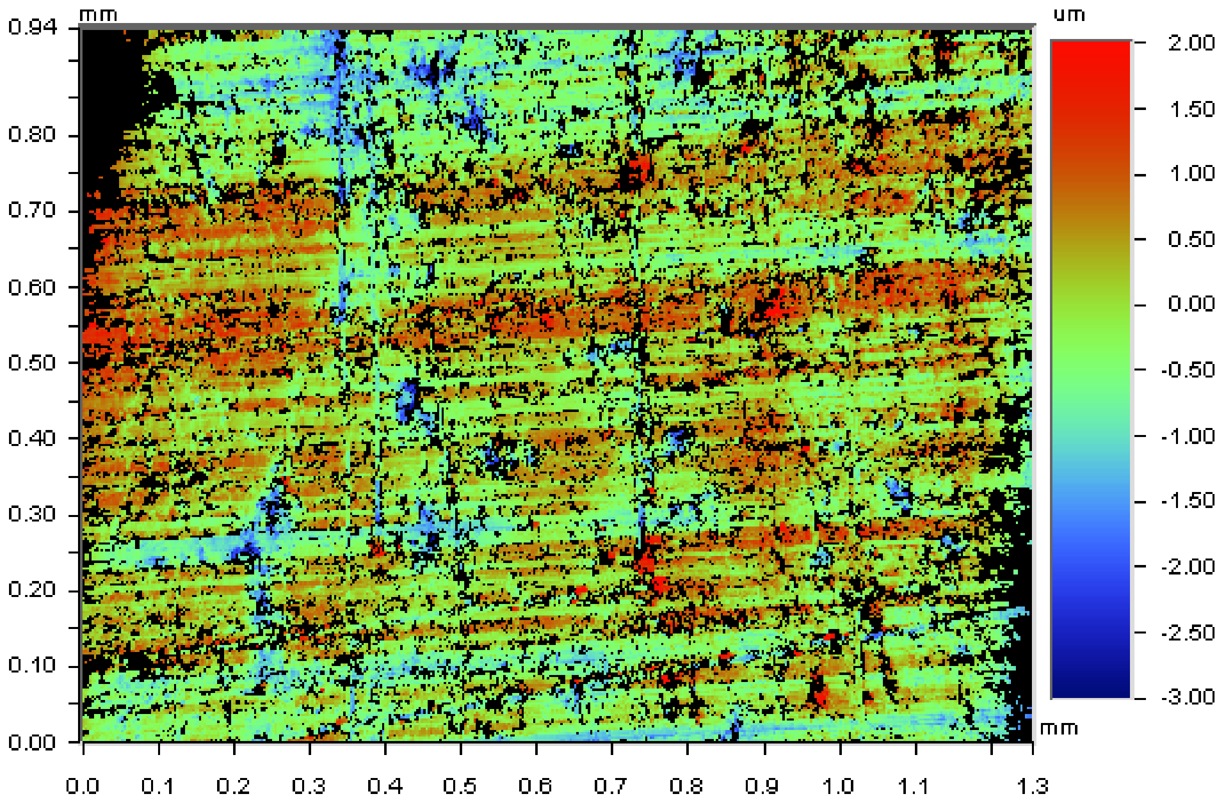
# Substrates


Stainless Steel


Aluminum


Silicon Wafer

# Roughness Values




Roughened Surface Crossly Sanded with Grit Size 2000

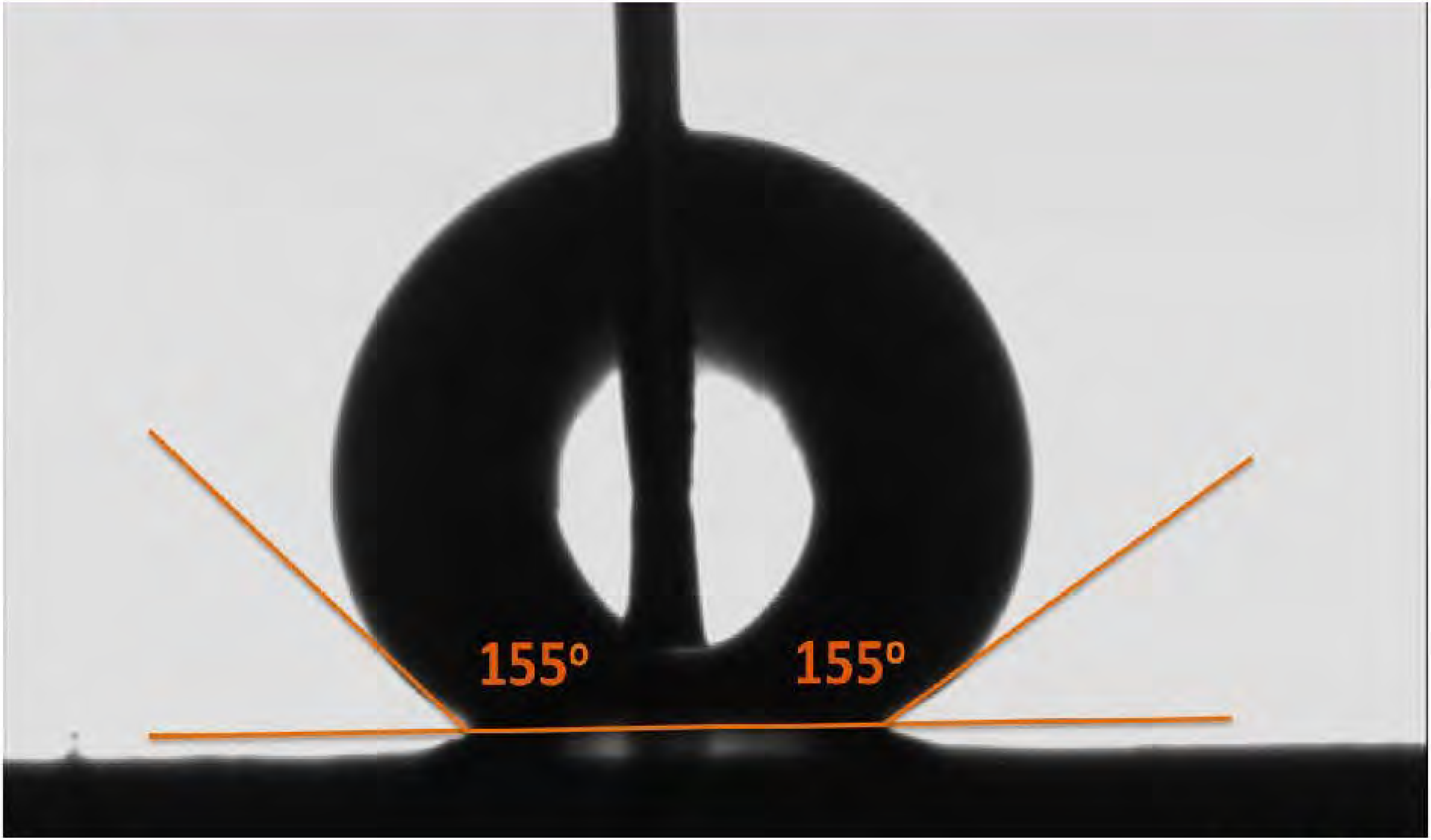
$R_a$-Roughness Average (499.97nm)

$R_q$- Root Mean Square (624.58 nm)

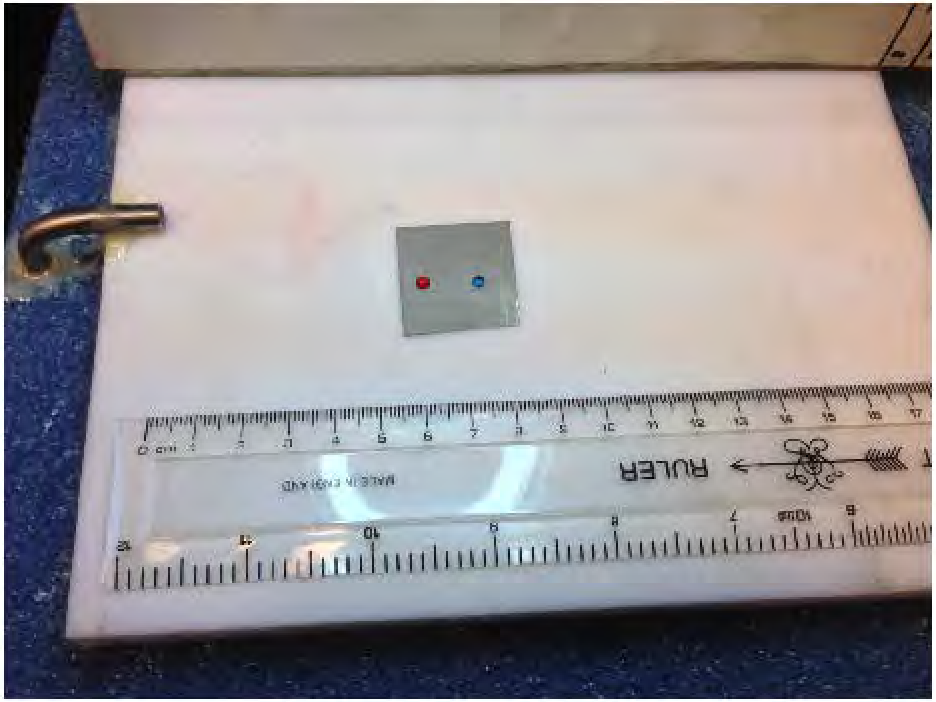
Sm- Surface Material Volume (26.36 $nm^3/nm^2$)

Sv- Surface Void Volume (66.06 $nm^3/nm^2$)

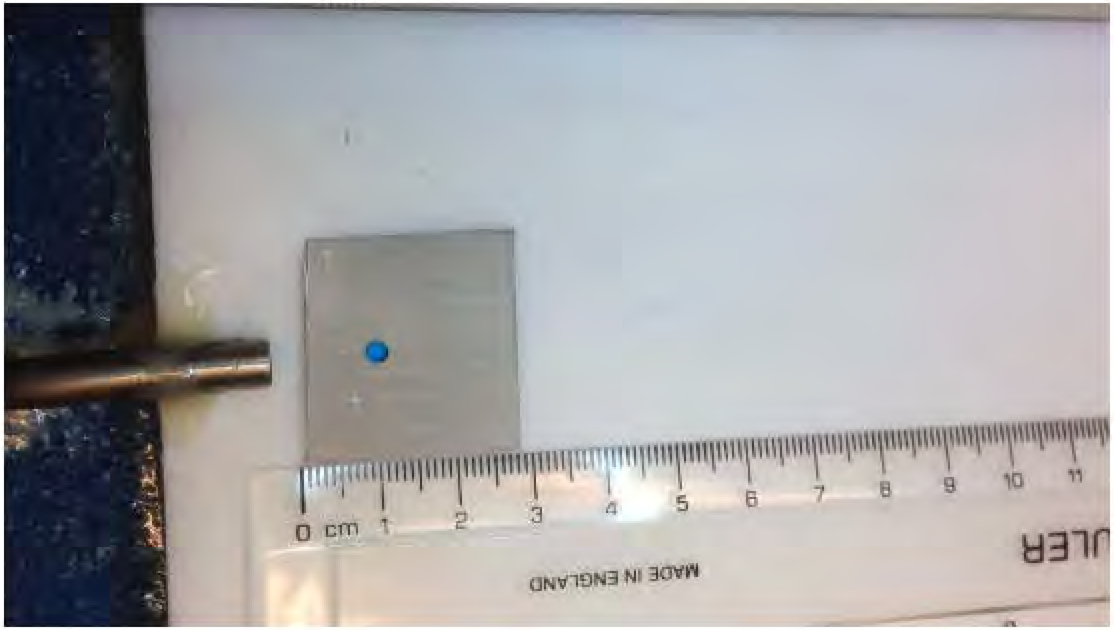
# Contact Angle



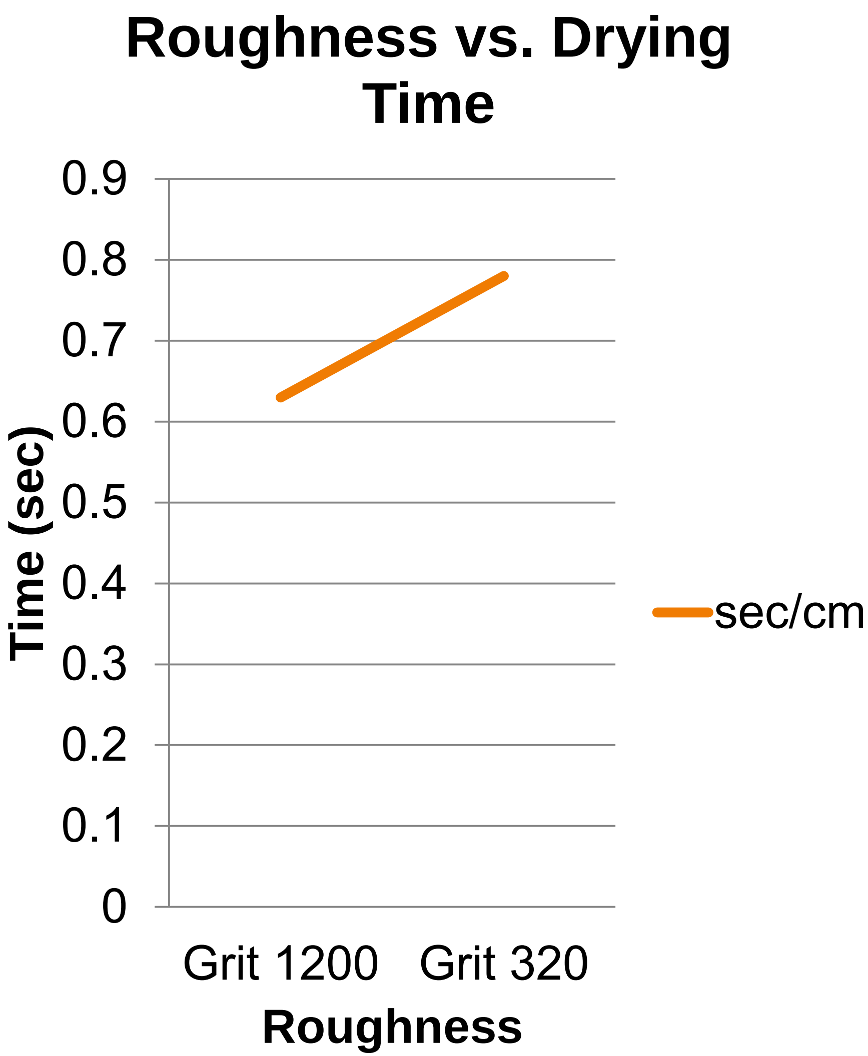
# Gas-Flow System



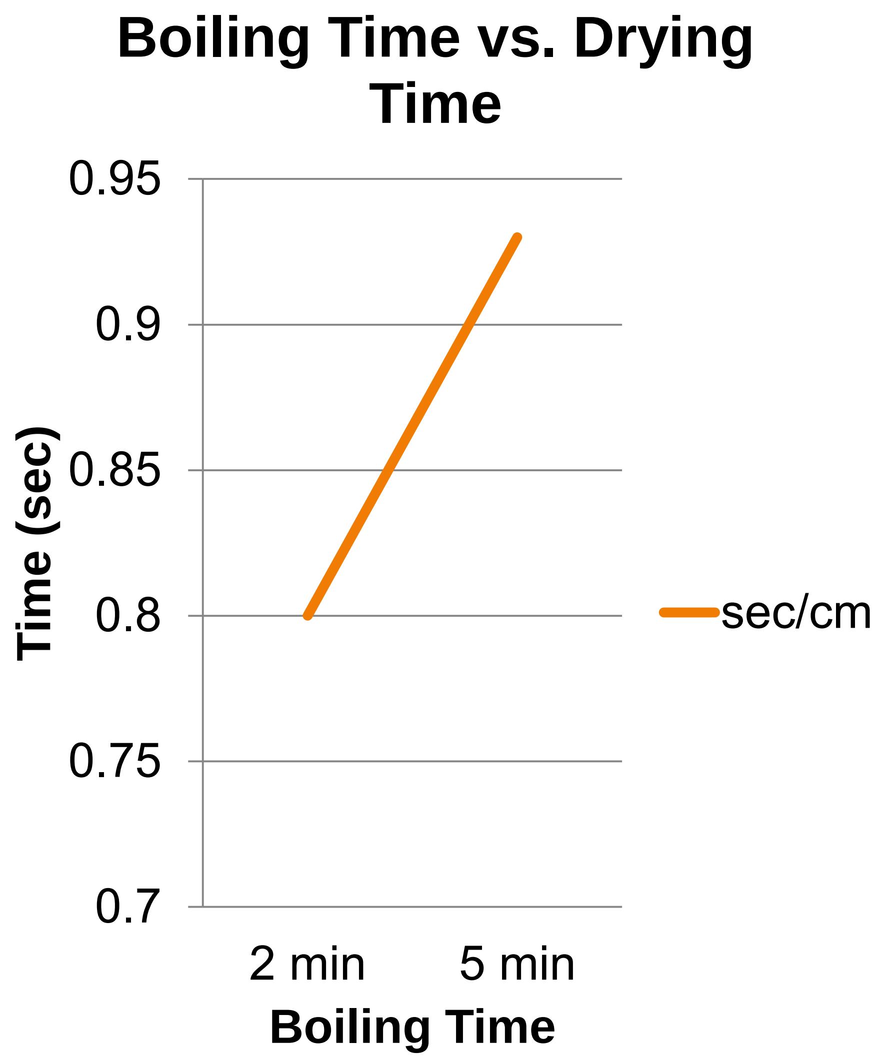
# High-speed Video



# Result



Roughness vs. Drying Time
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Time (sec)
sec/cm
Grit 1200
Grit 320
Roughness

Boiling Time vs. Drying Time
0.95
0.9
0.85
0.8
0.75
0.7
Time (sec)
sec/cm
2 min
5 min
Boiling Time

# Conclusion

- Lower roughness leads to faster drying time.
- An irregular surface can cause pinning regardless of silanization and contact angle, which disturbs the trend of hysteresis.
- Higher boiling time leads to faster drying time.
- Water has a faster drying rate than hexadecane.

# Lesson Plan

- **This lesson plan is directed for 9th-12th grade students.**
- **Reading about ice-cream.**
- **Learning to make ice-cream through a DOE optimization.**
- **The three factors are different weight percent of salt per ice, fat content in dairy and shaking time.**
- **Measured output will be rating and average of different ice-creams.**

# Future Work

- Different type of liquids
- Durability
- Using the optimization from DOE to further explore factors.

# Acknowledgement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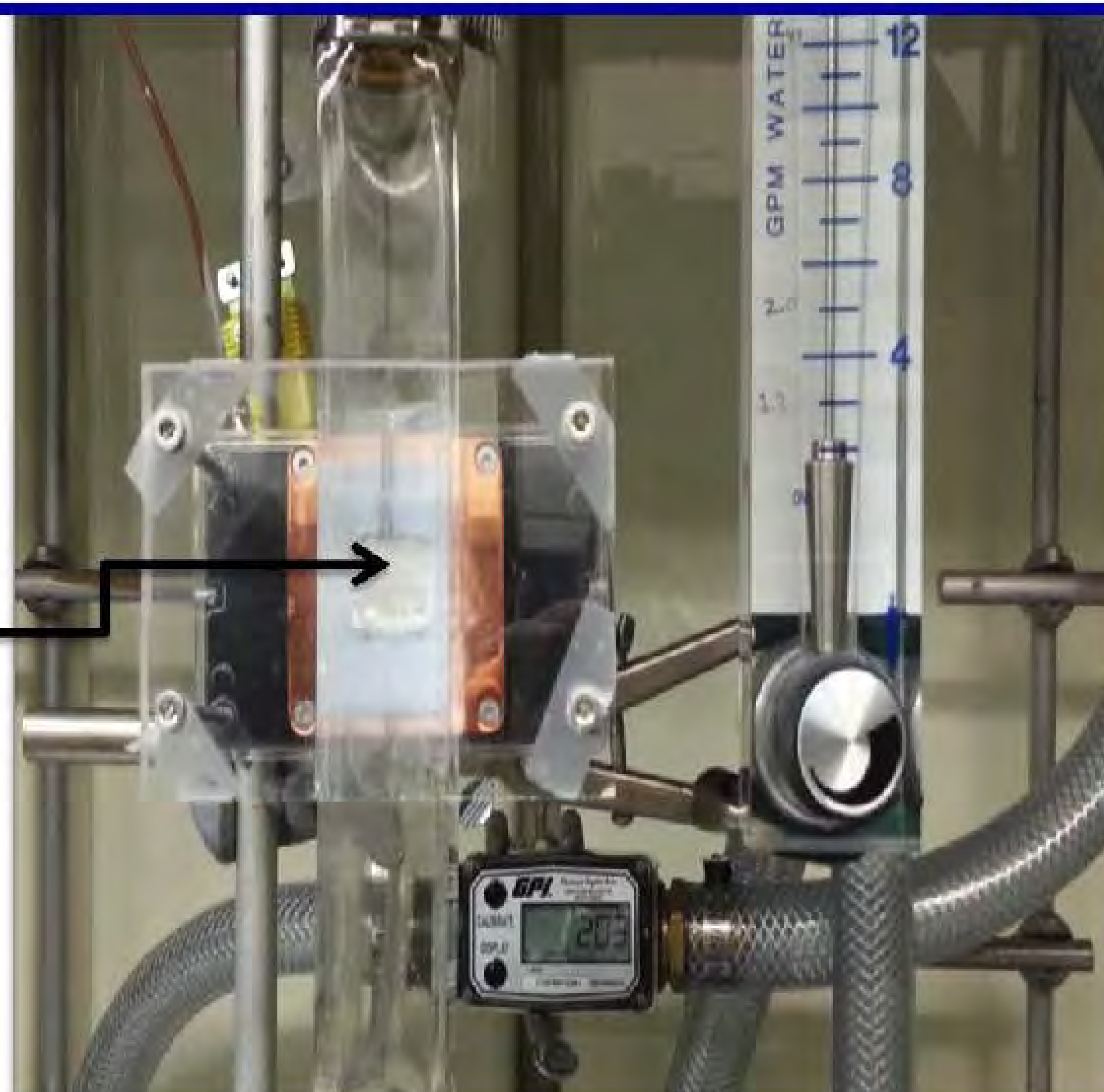
# Questions?

# Flow System

Al Substrate



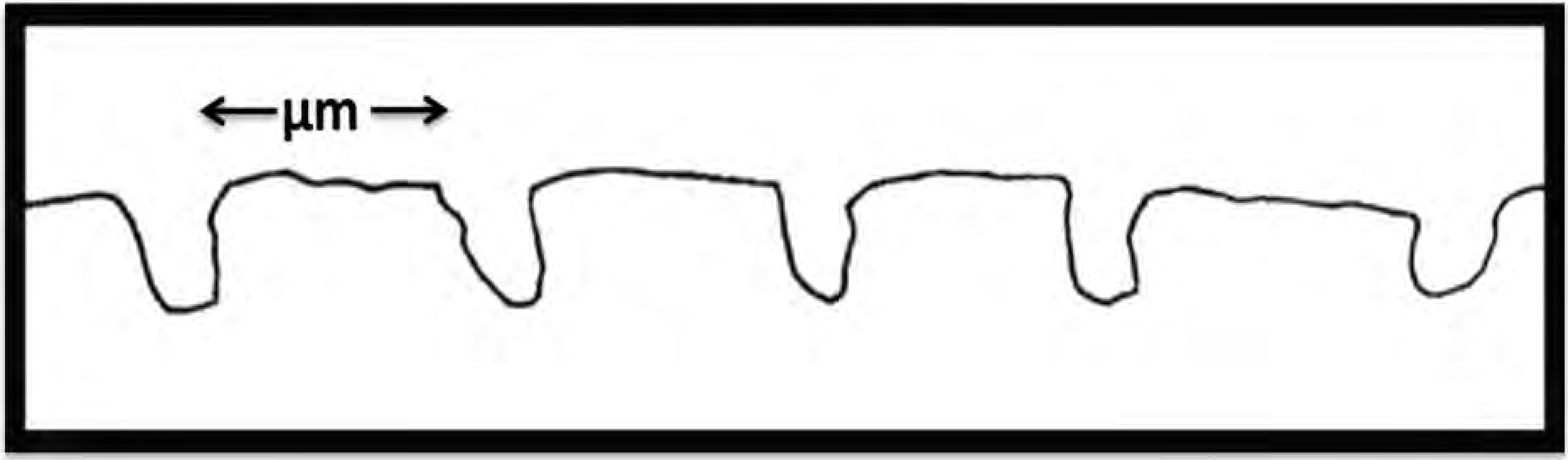

Flow Cell

# Creating Reentrant Surface

**Before Sanding**

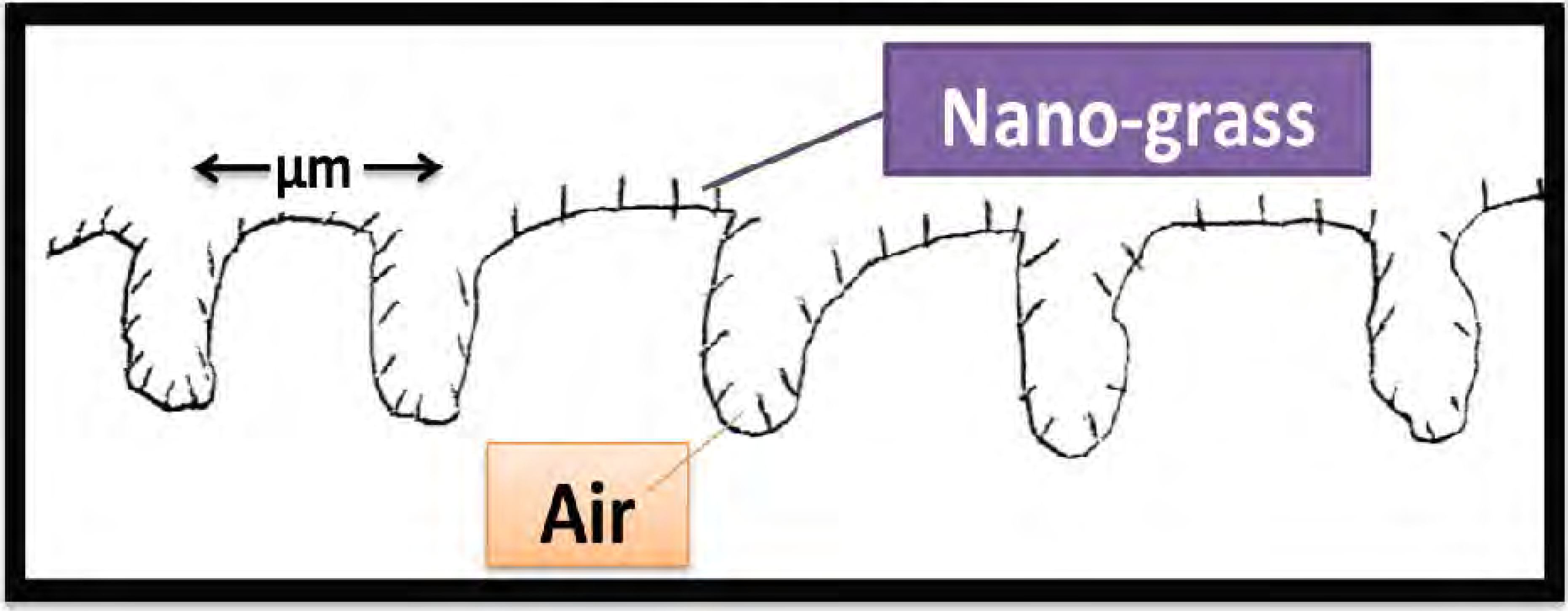
# After Sanding

## Micro-scale

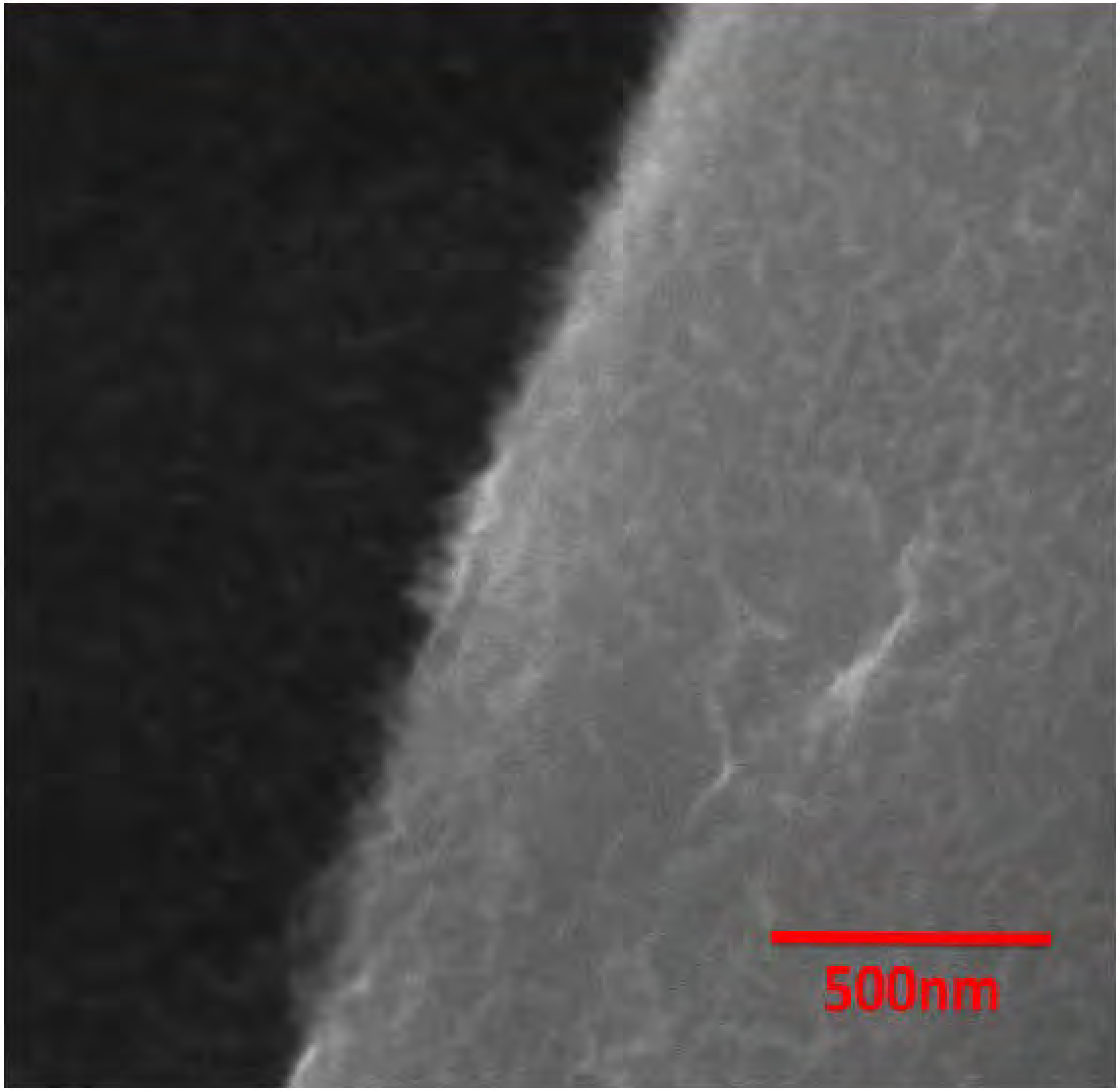


# Nano-grass Growth

**Nano-scale**

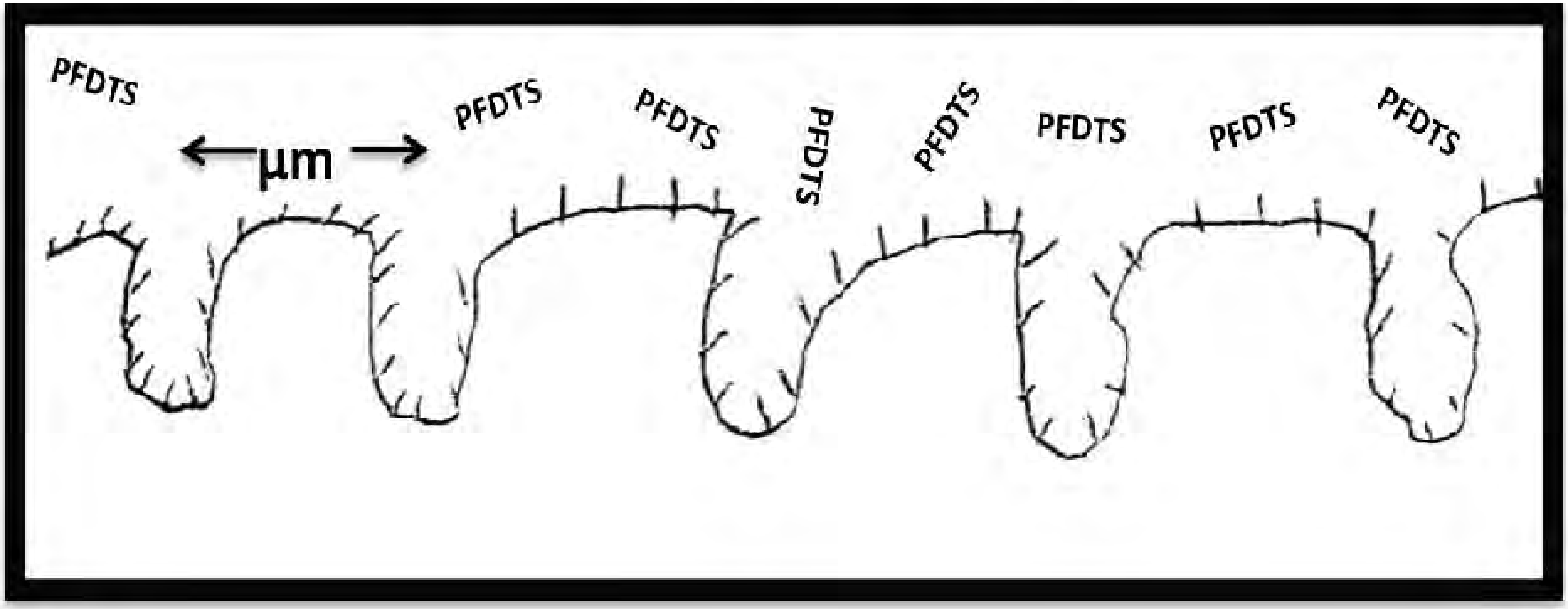


# SEM Image



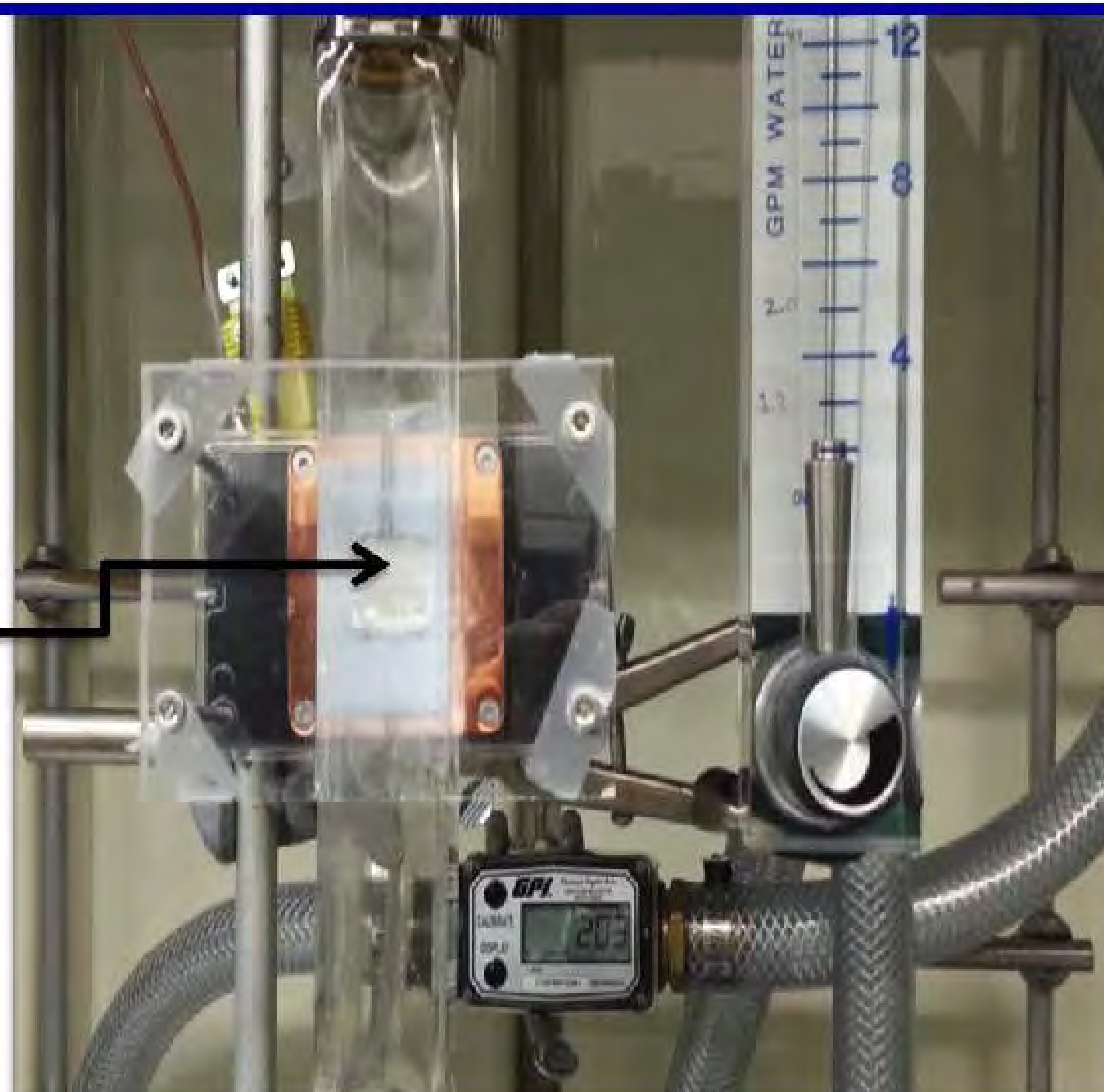
# Low Surface Energy

## Low Surface Energy



# Flow System

Al Substrate




Flow Cell

# Trapping Plastron

Dry

Under Water